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PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

N05/4/CHEMI/HP2/ENG/TZ0/XX+

88056102

CHEMISTRY
HIGHER LEVEL
PAPER 2

Monday 7 November 2005 (afternoon)

2 hours 15 minutes

Candidate session number

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.

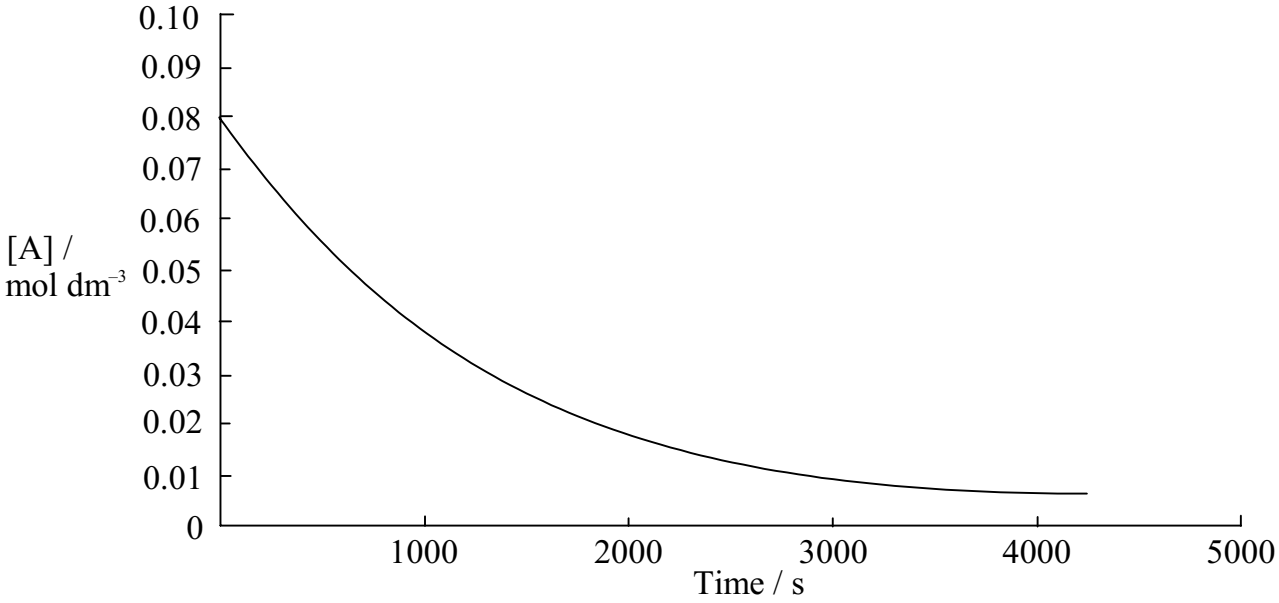
SECTION A

*Answer **all** the questions in the spaces provided.*

1. An equation for the decomposition of substance **A** is

$$2\mathbf{A} \rightarrow 2\mathbf{B} + \mathbf{C}$$

A graph showing the change in concentration of **A** against time as the reaction proceeds at a particular temperature is shown below.



(a) Define the term *half-life* of reaction. *[1]*

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(b) Use the graph to measure values of half-life of reaction, starting from *[2]*

time = zero . . . . . .

time = 2000 s . . . . . .

(c) Deduce the order of the reaction with respect to **A**, giving a reason for your choice, and write the rate expression for the reaction. *[3]*

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(This question continues on the following page)

(Question 1 continued)

(d) For a different reaction, between compounds **D** and **E**, the rate expression is

$$\text{rate} = k[\text{D}]^2[\text{E}]$$

Calculate the value of k, including units, for the reaction when the concentrations of both **D** and **E** are 1.35×10^{-2} mol dm^{-3} and the reaction rate is 3.75×10^{-5} mol dm^{-3} min^{-1}. *[3]*

2. A sample of germanium is analysed in a mass spectrometer. The first and last processes in mass spectrometry are vaporization and detection.

(a) (i) State the names of the other three processes in the order in which they occur in a mass spectrometer. *[2]*

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(ii) For each of the processes named in (a) (i), outline how the process occurs. *[3]*

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(b) The sample of germanium is found to have the following composition:

Isotope	^{70}Ge	^{72}Ge	^{74}Ge	^{76}Ge
Relative abundance / %	22.60	25.45	36.73	15.22

(i) Define the term *relative atomic mass*. *[2]*

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(ii) Calculate the relative atomic mass of this sample of germanium, giving your answer to two decimal places. *[2]*

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(c) Use the Aufbau principle to write the electron configuration of an atom of germanium. *[1]*

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(This question continues on the following page)

(Question 2 continued)

(d) The successive ionization energies of germanium are shown in the following table:

	1st	2nd	3rd	4th	5th
Ionization energy / kJ mol^{-1}	760	1540	3300	4390	8950

(i) Identify the sub-level from which the electron is removed when the first ionization energy of germanium is measured. *[1]*

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(ii) Write an equation, including state symbols, for the process occurring when measuring the second ionization energy of germanium. *[1]*

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(iii) Explain why the difference between the 4th and 5th ionization energies is much greater than the difference between any two other successive values. *[2]*

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3. This question is about Period 3 elements and their compounds.

(a) Explain, in terms of their structure and bonding, why the element sulfur is a non-conductor of electricity and aluminium is a good conductor of electricity. *[4]*

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(b) Explain, in terms of its structure and bonding, why silicon dioxide, SiO_2, has a high melting point. *[2]*

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(c) Silicon tetrachloride, $SiCl_4$, reacts with water to form an acidic solution.

(i) Explain why silicon tetrachloride has a low melting point. *[2]*

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(ii) Write an equation for the reaction of silicon tetrachloride with water. *[1]*

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4. One of the alcohols containing four carbon atoms exists as optical isomers.

(a) Give the structural formula and name of this alcohol and explain why it exists as optical isomers. Outline how these two isomers could be distinguished. *[4]*

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(b) When concentrated phosphoric acid is added to one of these optical isomers and the mixture is warmed, two isomeric organic products are formed. Give the structural formula and name of one of these products and identify the type of reaction occurring. Outline a simple chemical test for the functional group present in this product. *[4]*

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SECTION B

*Answer **two** questions. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

5. Throughout this question, use relevant information from the Data Booklet.

(a) Define the term *standard enthalpy change of formation*, and illustrate your answer with an equation, including state symbols, for the formation of nitric acid. *[4]*

(b) Propyne undergoes complete combustion as follows:

$$C_3H_4(g) + 4O_2(g) \rightarrow 3CO_2(g) + 2H_2O(l)$$

Calculate the enthalpy change of this reaction, given the following additional values:

$$\Delta H_f^{\ominus} \text{ of } CO_2(g) = -394 \text{ kJ mol}^{-1}$$
$$\Delta H_f^{\ominus} \text{ of } H_2O(l) = -286 \text{ kJ mol}^{-1}$$ *[4]*

(c) Predict and explain whether the value of $\Delta S^{\ominus}$ for the reaction in part (b) would be negative, close to zero, or positive. *[3]*

(d) Propyne reacts with hydrogen as follows:

$$C_3H_4(g) + 2H_2(g) \rightarrow C_3H_8(g) \qquad \Delta H^{\ominus} = -287 \text{ kJ}$$

Calculate the standard entropy change of this reaction, given the following additional information:

$$S^{\ominus} \text{ of } H_2(g) = 131 \text{ J K}^{-1} \text{ mol}^{-1}$$ *[3]*

(e) Calculate the standard free energy change at 298 K, $\Delta G^{\ominus}$, for the reaction in part (d). Use your answer and relevant information from part (d). If you did not obtain an answer to part (d), use $\Delta S^{\ominus} = -360 \text{ J K}^{-1}$ (this is not the correct value). *[3]*

(f) The lattice enthalpy of an ionic compound can be calculated using a Born-Haber cycle. Using lithium fluoride as the example, construct a Born-Haber cycle, labelling the cycle with the formulas and state symbols of the species present at each stage. *[6]*

(g) Two values of the lattice enthalpies for each of the silver halides are quoted in the Data Booklet. Discuss the bonding in silver fluoride and in silver iodide, with reference to these values. *[2]*

6. (a) The equation for the decomposition of hydrogen iodide is

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad \Delta H^{\ominus} = -52 \text{ kJ}$$

Predict and explain the effect on the position of equilibrium of

(i) increasing the pressure, at constant temperature. *[2]*

(ii) increasing the temperature, at constant pressure. *[2]*

(iii) adding a catalyst, at constant temperature and pressure. *[2]*

(b) Deduce the expression for K_c for the forward reaction. *[1]*

(c) The equilibrium formed during this reaction was investigated in two experiments carried out at different temperatures. The results are shown in the table below.

Experiment number	Initial concentration / mol dm^{-3}			Equilibrium concentration / mol dm^{-3}		
	[HI]	[H_2]	[I_2]	[HI]	[H_2]	[I_2]
1	0.06	0.00	0.00		0.01	
2	0.00	0.04	0.04	0.04		

(i) For each experiment, deduce the concentrations of the other species present at equilibrium. Calculate the values of K_c for the forward reaction for each experiment. *[6]*

(ii) Use the two calculated values of K_c to deduce which of the two experiments was carried out at the higher temperature, and explain your choice. (If you were not able to calculate the values of K_c in (c)(i), assume that the values are 0.1 for experiment 1 and 0.2 for experiment 2, although these are not the correct values.) *[2]*

(d) The equilibrium reached when ethanoic acid is added to water can be represented by the following equation:

$$CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

Define the terms Brønsted-Lowry acid and Lewis base, and identify **two** examples of each of these species in the equation. *[4]*

(e) The pH of a solution is 4.8. Using information from Table 17 of the Data Booklet, deduce and explain the colours of the indicators bromophenol blue and phenol red in this solution. *[3]*

(f) Calculate the pH of a buffer solution containing 0.0500 mol dm^{-3} of ethanoic acid ($K_a = 1.74 \times 10^{-5}$) and 0.100 mol dm^{-3} of sodium ethanoate. *[3]*

7. (a) Electrolysis can be used to obtain chlorine from molten sodium chloride. Write an equation for the reaction occurring at each electrode and describe the two different ways in which electricity is conducted when the cell is in operation. *[4]*

(b) In one experiment involving the electrolysis of molten sodium chloride, 0.1 mol of chlorine was formed. Deduce, giving a reason, the amount of sodium formed at the same time. *[2]*

(c) In another experiment involving the electrolysis of molten sodium chloride, the time of the electrolysis was halved and the current increased from 1 amp to 5 amp, compared to the experiment in (b). Deduce the amount of chlorine formed, showing your working. *[2]*

(d) If dilute aqueous sodium chloride is electrolyzed, a different product is obtained at each electrode. Identify the product formed at each electrode and write an equation showing its formation. *[4]*

(e) Two reactions occurring in the manufacture of bromine from sea water are

I $Cl_2(g) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(g)$

II $Br_2(g) + SO_2(g) + 2H_2O(l) \rightarrow 2HBr(g) + H_2SO_4(g)$

(i) Explain, by reference to electrons, why reaction I is referred to as a redox reaction. *[2]*

(ii) State and explain whether SO_2 is reduced or oxidized in reaction II by referring to the oxidation numbers of sulfur in this reaction. *[3]*

(f) Define the term *standard electrode potential* of an element. Table 15 of the Data Booklet contains $E^\ominus$ values for two reactions involving $O_2(g)$. Identify the $E^\ominus$ value of the reaction that could be used to oxidize bromide ions and explain your reasoning. Construct a balanced equation for the oxidation of bromide ions using this reaction and calculate the cell potential. *[8]*

8. The molecular formula C_4H_9Br represents four structural isomers, all of which can undergo nucleophilic substitution reactions with aqueous sodium hydroxide. An equation to represent all these reactions is

$$C_4H_9Br + NaOH \rightarrow C_4H_9OH + NaBr$$

(a) Explain what is meant by the term *nucleophilic substitution*. *[2]*

(b) The main mechanism for a tertiary halogenoalkane is S_N1. Give the equations for this substitution reaction of the tertiary isomer of C_4H_9Br. Show the structures of the organic reactant and product and use curly arrows to show the movement of electron pairs. *[4]*

(c) The main mechanism for a primary halogenoalkane is S_N2. Give the mechanistic equation for this substitution reaction of the straight-chain primary isomer of C_4H_9Br, showing the structures of the organic reactant and product, and using curly arrows to show the movement of electron pairs. *[4]*

(d) Give a structural formula for the secondary isomer and for the other primary isomer. State the name of each isomer. *[4]*

(e) State and explain which of the compounds C_4H_9Br and C_4H_9OH has the higher boiling point. *[2]*

(f) The four structural isomers with the formula C_4H_9Br were investigated by mass spectrometry. One of the isomers showed molecular ion peaks at m/z = 136 and 138 and fragmentation peaks at m/z = 57 and 42. Use this information to deduce what you can about this isomer, showing your reasoning. *[4]*

(g) The ^1H NMR spectrum of one of the four structural isomers of C_4H_9Br has four peaks with areas in the ratio 3 : 3 : 2 : 1. Deduce whether this compound is a primary, secondary or tertiary isomer. *[1]*

(h) One of the alkanes from which an isomer of C_4H_9Br can be formed has two peaks, with areas in the ratio 9 : 1, in its ^1H NMR spectrum. Deduce the structure of this alkane. *[1]*

(i) Write an equation for the formation of C_4H_9Br starting from C_4H_{10}. Explain what is meant by the term *homolytic fission* and identify a free radical involved in this reaction. *[3]*